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NOTE ON THE PHYSIOLOGY OF THE CARDIAC NERVES OF THE CALF

presented

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We were able to experiment upon but one calf, and had we any expectation of continuing this investigation in the near future we should not publish the results of this experiment at present. Our results, however, seem to us so satisfactory and conclusive that we feel justified in describing them. The heart of the calf is so large and the rate of beat so slow that every change can be followed by the eye with great ease, and the effects of stimulating various nerves can be determined more satisfactorily in some respects than when recording apparatus is applied to the smaller and more rapid hearts of the animals ordinarily used in the laboratory.

The calf upon which we experimented had been used by Dr. Curtis in a lecture demonstration and had been under the influence of ether for some time, but the heart was beating vigorously, and the blood pressure, which was recorded by the mercury manometer in the usual manner, was moderately high (100 mm. of mercury).

Stimulation of the vagus.—Stimulation of the peripheral end of the vagus with currents of moderate intensity caused slowing of both auricle and ventricle. In a number of cases, however, the ventricle was slowed very decidedly, while the rate of the auricle was but slightly affected. This result agrees with that described by Franck* for the dog, but differs from the results obtained by most experimenters for this animal. McWilliam,† Bayliss and Starling,‡ and Roy and Adami,§ for example, speak of the auricles in the dog as being

* Franck, *Archives de Physiologie*, 5. s., ii (1890), 403.
† McWilliam, *Journal of Physiology*, ix (1888), 345.
‡ Bayliss and Starling, *ib.* xiii (1892), 407.
§ Roy and Adami, *Phil. Trans.*, clxxxiii (B), (1892), 199.

more easily slowed by stimulation of the vagus than are the ventricles. In none of the several stimulations of the vagus in the calf did we observe a slowing of the auricles without a slowing of the ventricles also.

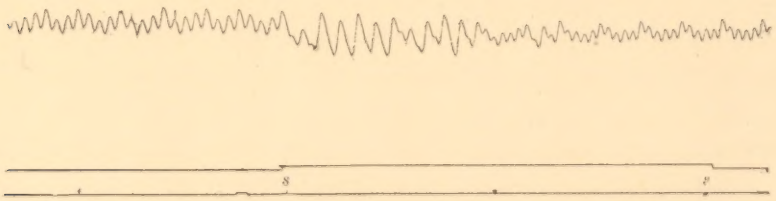
It is interesting to note that sometimes there was an after-effect of the stimulation of the vagus in which the effect upon the ventricle was more marked than that upon the auricles. Thus in one case, after a long-continued stimulation of the vagus, during which auricles and ventricles were both slowed but continued to beat together, the ventricles did not return to their normal rate, while the auricles did return, and it was observed that the ventricles were following at times every auricular beat, and at other times only every second beat. While this slow rate of the ventricles continued, the accelerators were stimulated and the ventricles began at once to follow all the auricular beats. The rate of the auricles, however, was but slightly increased. After the cessation of the stimulation of the accelerators the slow irregular beat of the ventricles returned.

Apparently these results and similar ones obtained in the experiments upon the opossum can be explained satisfactorily by supposing the conductivity of the muscle fibres connecting the auricle and ventricle to have been altered by the stimulation of the nerves.* After the prolonged stimulation of the vagus, the conductivity of these muscle fibres seemed to be depressed for some time; stimulation of the accelerators apparently caused a temporary increase of their irritability, and as a consequence the ventricle followed every auricular beat. So, also, the decreased conductivity of these fibres resulting from the action of the vagus may explain why stimulation of these nerves at times caused a slowing of the ventricles while the auricles were not much affected. Possibly this factor—the changes in the conductivity of the muscle fibres between the auricles and ventricles—has not received sufficient attention from some of the physiologists who have discussed the relative effects of the stimulation of the vagus and accelerator nerves upon the different parts of the heart.

* *Cf.* Gaskell, *Journal of Physiology*, iv (1883), 100; McWilliam, *op. cit.* 367; Bayliss and Starling, *op. cit.* 412.

Stimulation of the peripheral end of the vagus with a very weak current caused in one or two cases a slight acceleration of the heart, as is often observed in the dog.

Accelerator nerves.—We stimulated two nerves passing from the spinal nerves to the stellate ganglion—the *ramus communicans* from the second spinal nerve and a nerve accompanying the vertebral artery (the "*nervus vertebralis*"). Stimulation of both of these nerves caused acceleration of the heart; the results differed, however, in a very interesting manner according as one or the other nerve was stimulated. The immediate effect of stimulating the vertebral nerve was to cause an acceleration of the auricles, but a slowing of the ventricles due to failure of the latter to follow all of the beats of the former. Frequently, if the stimulation was continued for some time, the ventricles began to follow all the auricular beats. We have in this case an illustration of how stimulation of the accelerator nerves can cause an actual slowing of the ventricles—a possibility recently pointed out by Engelmann.* This primary slowing was always obtained whatever the strength of the stimulus used; the acceleration of the auricles and the slowing of the ventricles was most marked, however, with strong stimuli.



Stimulation (*s-s*) of the vertebral nerve; the secondary coil was 12 cm. from the primary. In the early part of the stimulation the ventricles failed to follow all the auricular beats, and the result was a slight slowing of the pulse; later there was an acceleration, the ventricles now beating at the same rate as the auricles. Time in intervals of 10 seconds. Curve to be read from left to right.

During the stimulation, the result of which is shown in the accompanying figure, the secondary coil of the induction apparatus was 12 cm. from the primary coil; the rate of the auricles and ventricles

* Engelmann, Pflüger's *Archiv*, lxv (1896), 161.

before stimulation was 20 beats in 10 seconds. In the first 10 seconds during stimulation the auricle gave 24 beats, the ventricle but 19, as it failed to follow all the auricular beats; in the second period of 10 seconds both auricle and ventricle gave 26 beats and the latter followed the former throughout. In a second stimulation the stimulus was stronger, the coil being at 10 cm., before stimulation the auricle and ventricle were beating at the rate of 19½ in 10 seconds; during stimulation the auricles beat at the rate of 26 in 10 seconds, while the ventricles, following only every second auricular beat, had a rate of 13 in 10 seconds. Later the rate of the ventricle became more rapid, following all the auricular beats.

The effect upon the heart of stimulating the 2nd *ramus communicans* differed from the above in that both auricle and ventricle were uniformly accelerated. The following figures give the result of stimulating the 2nd *ramus communicans* with the coil at 10 cm. (the same strength of current as was used in the second of the above stimulations of the vertebral). The rate of both auricle and ventricle before stimulation was 20 in 10 seconds; during the first 10 seconds the rate increased to 23½, during the second 10 seconds it was 28, during the third, 28½, and during the first 10 seconds after stimulation it was 29½. Throughout the stimulation each auricular beat was followed by a ventricular beat, and this occurred also when stimuli of various intensities were used.

The above facts show that in this individual at least the accelerator fibres passing through the vertebral nerve were different from those in the 2nd *ramus communicans*; stimulation of each nerve caused acceleration of the auricle, but the fibres of the 2nd *ramus communicans* evidently had more effect upon the ventricle than did those of the vertebral. This difference may be explained by supposing that the *ramus communicans* contained more fibres passing to the ventricle than did the vertebral nerve, or, and this is perhaps more probable, by supposing that it contained more fibres, stimulation of which caused the conductivity of the muscle fibres connecting the auricles and ventricles to be increased. In any case, it is certain that the accelerator fibres in the two nerves differed in either their ana-

tomical or physiological relations to the heart. Bayliss and Starling* observed a similar separation of the functions of the accelerator fibres in the dog and ascribed the result to the earlier fatigue of one set of fibres; the element of fatigue can probably be excluded from our experiment upon the calf, for both nerves had received the same treatment.

We also tried the effect of stimulating the inhibitory and accelerator nerves simultaneously. The peripheral end of one vagus was stimulated with an induced current produced by the slow interruption of the primary current with the "Schlagwähler"; both auricles and ventricles were slowed. While the stimulation of the vagus was continued the accelerators were stimulated; the rate of both auricles and ventricles was accelerated.

Thus the antagonism of the inhibitory and accelerator nerves, already found to hold in the case of the ventricles of other animals, is found to occur in the calf also, and holds for the auricles as well as for the ventricles.†

* Bayliss and Starling, *op. cit.* p. 416.

† Since the completion of my paper upon the relation of the inhibitory to the accelerator nerves of the heart (*Journal of Experimental Medicine*, ii (1897), 151), I have repeatedly observed directly the effect upon the auricle and ventricle of the simultaneous stimulation of these nerves in the dog. With the strength of current which I used, a ventricular always followed an auricular beat, and in all cases the effect upon the rate of the auricle as well as upon that of the ventricle, was approximately the algebraic sum of the effects produced by stimulating the nerves separately. An "independent ventricular rhythm" which might complicate the results was never caused by the stimulation of the vagus in my experiments.—R. H.